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INVENTION DISCLOSURE

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Incrementally adaptable forward link data rate for Connexion by Boeing

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STATE OF DEVELOPMENT (See Remarks On Back)

DATE CONCEIVED		DATE BUILT	DATE SATISFACTORILY TESTED	
	☐ CONCEPT ONLY ☐ PROVEN ANALYTICALLY ☐ DESIGN COMPLETE			☐ PROTOTYPE ☐ IN PRODUCTION ________ DATE

D

APPLICATION OF THE INVENTION

PRODUCT/PROGRAM	PRODUCTION RELEASE E.G. PRR NO.	DATE
Connexion by Boeing		

POTENTIAL CUSTOMER(S) IN ADDITION TO BOEING

E

DISCLOSURE OF INVENTION OUTSIDE BOEING

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PUBLISHED	PUBLICATION NAME	DATE	VOLUME NO.	PAGE
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F

DEVELOPMENT HISTORY

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01-404 EEG 6-19-01

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EXHIBIT B

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DISCLOSURE NO	DATE RECEIVED		IPE	Lead IPE	Tech Code	IPA
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Invention Description: Provide a detailed description of your invention.

Problem Definition and Solution Options

The problem addressed by this patent occurs while running multiple forward links simultaneously near their optimum SNR when all of a region on the earth is covered by a satellite beam, for example, CONUS. For the case of different RF power losses from the satellite to the earth receivers, in the current plan for Connexion, the data rate must be adjusted to support the weakest communication link; other planes in lower loss regions have a larger amount of unusable link margin (Figure 1).

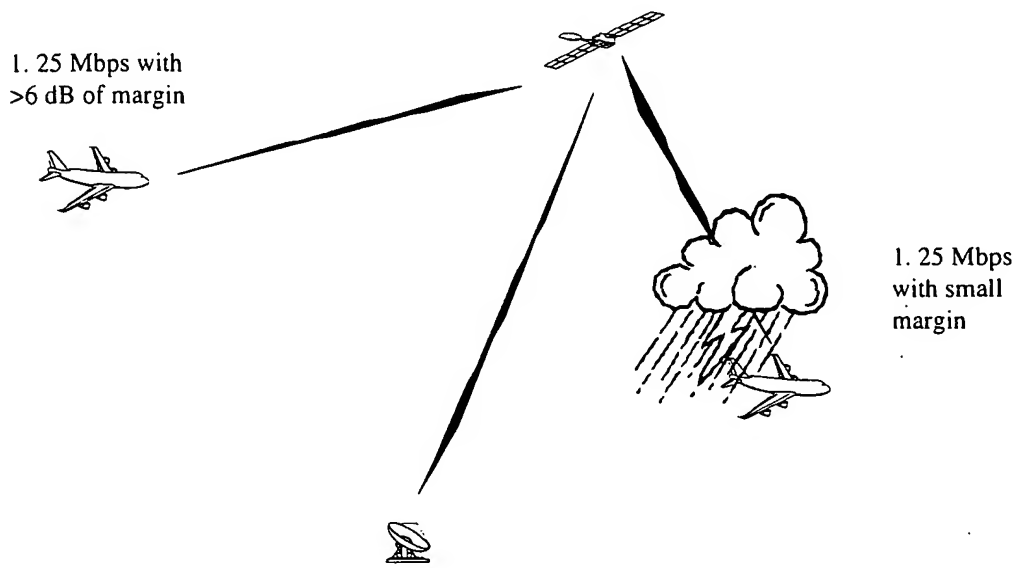

Figure 1. Current Connexion Forward Link Data Rate Management Architecture

The proposed method assigns user receive modem(s) that possess similar link margin, a physical layer data rate commensurate with the communication link losses for the region of interest. As a result, proper link margin is maintained for low BER operation in the designated region. The user receive modem(s) in a region with similar forward link margin could be assigned the same data rate (Figure 2).

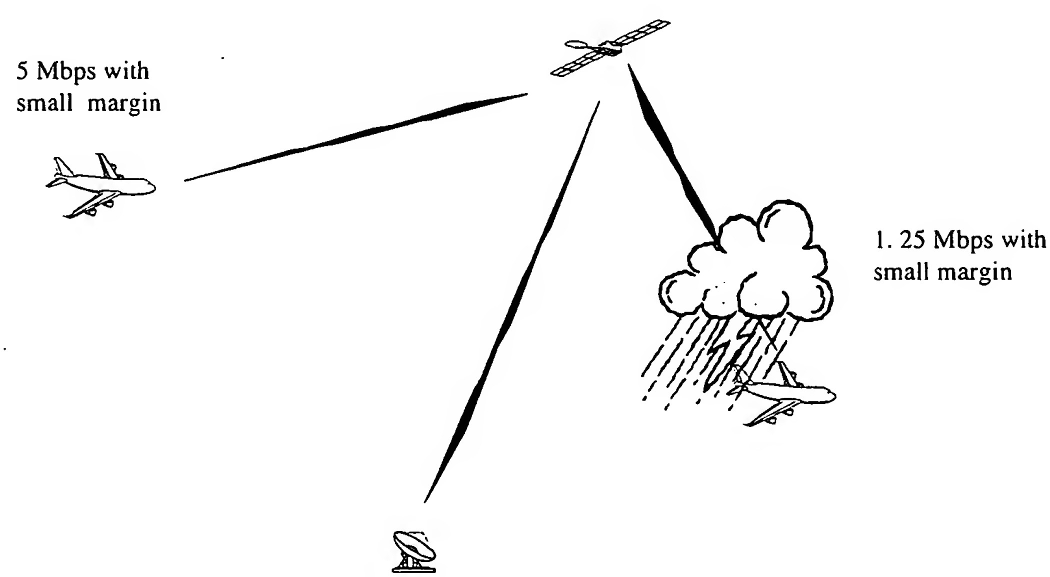

Figure 2. Proposed Connexion Forward Link Data Rate Management Architecture

Consider the case where theTelstar 6 geostationary satellite is supporting user receive modems in Miami, Florida while it is raining and in San Diego, California while it is clear. A 6 dB difference in link loss between the satellite and the two airplanes in the two regions is possible. This is the case illustrated in Figure 1 where both planes are receiving the same data rate.

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The IP multicast data rate on the Forward Link is designed around the weakest part of the CONUS system. With the steep curve for bit error ratio (BER) as a function of Eb/No for the turbo coding used on Connexion, this means that the locations with less 'space loss-plus-other loss' have a great deal of excess link margin(Figure 3). The proposed invention uses this excess margin to provide an increased data rate to the areas that can support it. In turn, the ability to send the data at a higher rate to the areas with excess margin allows the lower link margin areas to send more packets, increasing the throughput for the effected user receive modems of the low margin areas. For the periphery of the satellite beam where the satellite RF power density is falling off, some level of data rate could simultaneously be provided to CONUS users and users on the periphery of CONUS so that all could receive at least some data rate capability on the forward link. There is also the instance at high latitudes where the scan loss strongly and negatively impacts the link margin. There are many possible link losses varying over CONUS, for example, airborne antenna type and airborne antenna orientation, and additional variances to the actual terms to the link margin that occur during operation of a broadcast satellite communication system. There are link losses that depend on variances in the manufacture of satellite communications hardware, for example, the receive antenna performance. There are link losses that depend on local environmental conditions and on region-specific interference and thermal noise.

It would be advantageous to send higher data rates for regions with lower loss. By design, there is steady RF power through the satellite transponder. In the proposed concept, the data rate varies up or down while keeping the RF power through the transponder fixed. To insure that the BER stays below a certain level, the base data rate can be adjusted to maintain the required Eb/No. To achieve efficientTCP throughput and yet spread each user's data to fill the transponder bandwidth, this disclosure proposes the use of variable length orthogonal spreading code, in addition to the spectral spreading due to use of a maximal length linear sequence(PN spreading).

How it works

The method maintains the required positive link margin by adjusting the coding gain for particular receive user receive modem(s). Increase in coding gain means a reduction in data rate. For Internet protocol applications and other applications that are sensitive to bit errors and packet errors for their throughput efficiency, it is necessary to operate at a low bit error rate (typically less than 10E-09). The method proposed in this invention achieves the link margin necessary to achieve a low bit error rate for multiple users experiencing various levels of RF loss on the satellite to ground link. The reduction in data rate is minimized to achieve sufficient yet not excessive link margin.

The proposed invention uses both the existing Code Reuse Multiple Access and variable length coding to keep the operational features that CRMA provides and to add the data rate adaptability that variable length coding provides. The product of the orthogonal code spreading factor and the associated data rate would be a constant equal to the highest data rate supportable for the planes serviced on a transponder. The CRMA code would be superimposed at the OQPSK symbol boundaries as illustrated in Figure 3.

This is a similar physical layer waveform design to GSM 3G. Refer for example to "Spreading Codes for Direct Sequence CDMA and Wideband CDMA Cellular Networks" by Dinan and Jabbari in IEEE Communication Magazine, September 1998. The use of variable length orthogonal codes design to adapt the data rate to maintain low BER for a coverage region and a number of user receive modems is new.

Variable Length Orthogonal Codes for Variable Data Rates

The use of variable length orthogonal codes in GSM 3G is for user data rate assignment. GSM uses these codes for providing different services with different data rate demands to a user and for uniquely addressing a user. An example of a variable length code tree that could be used for Connexion is illustrated in Figure 4.

The services for CBB are negotiated through the setup of the IP application that is running over it. User receive modems are addressed by the user receive modem-unique IP address. Variable length orthogonal codes are used to adapt the data rate for user receive modem(s) to achieve sufficiently low BER and low packet error ratio.

This approach compensates for transponder EIRP falloff with latitude and longitude and could allow extended latitude range for airplane operation. The proposed invention allows flexibility to accommodate multiple versions of those loss scenarios in 3 dB increments from 64 kbps to 8.192 Mbps (7 steps in 3 dB increments which is 21 dB of dynamic range).

The Connexion receiver would sync up with the PN spreading code just as it does now. Then, the new added step would be for it to sync up with the appropriately assigned orthogonal code. The coding tree for generating orthogonal codes in the preferred embodiment is the same as is used for the GSM 3G standard. The purpose for the assignment of the codes is different though.

After evaluating the communication link loss for a region, then the spreading code rate contributed by the variable length orthogonal code is set such that the spread code rate times the data rate is the lowest data rate of the channel. The concatenation of user payload digital bit stream, variable length spreading code and long PN code is not new; it is in the basic design for GSM 3G. The use of variable length, orthogonal coding to set the IP multicast , forward link data rate is new. This design would address Connexion's problem in covering CONUS, where the satellite beam is large and there are spot regions that may require special link margin attention.

This is to be contrasted to pure GSM 3G orthogonal tree code assignment where the time slots are assigned to various users and there is no resources used for IP addressing. For the Connexion data delivery architecture, IP addressing and IP address packet filtering are used.

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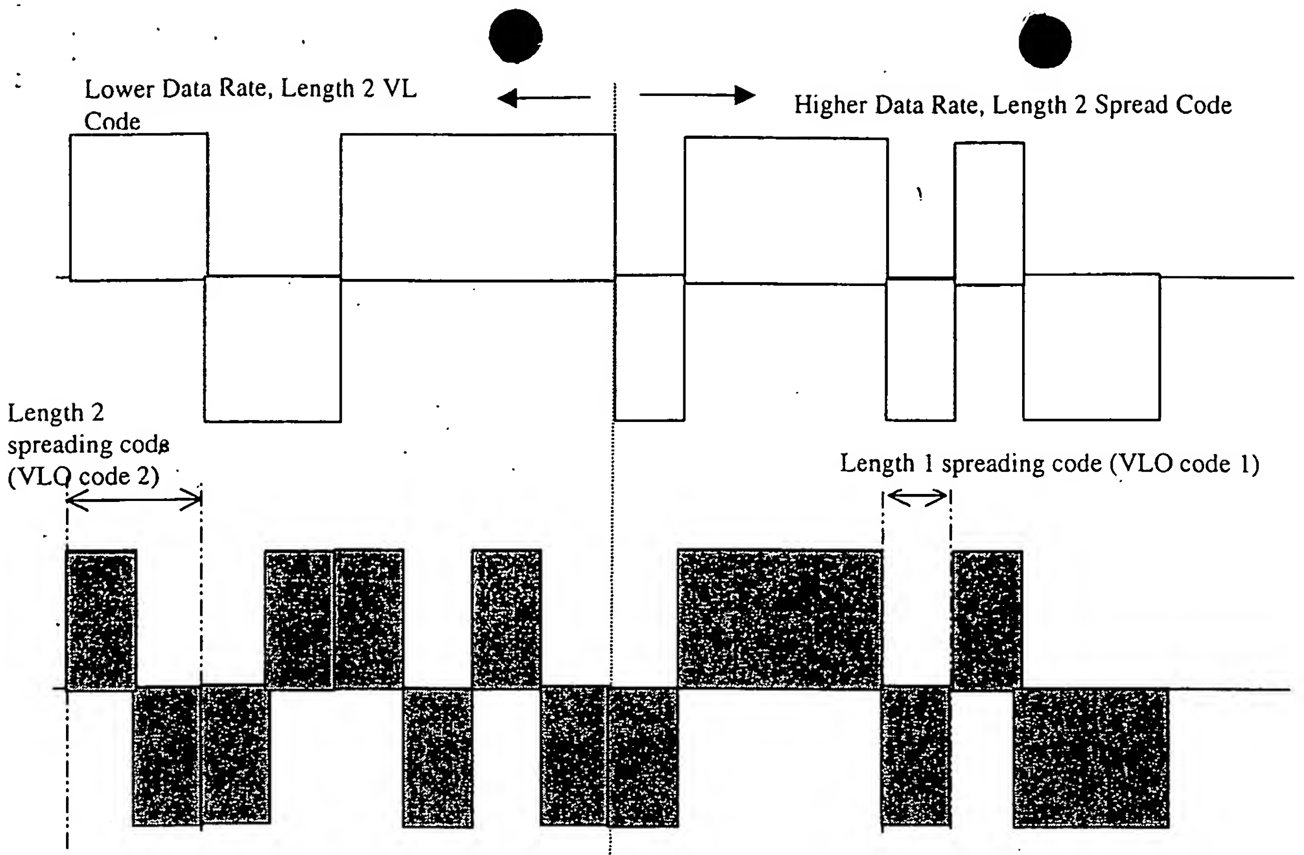

Figure 3. An embodiment of Use of the Variable Length Orthogonal Spreading Code into the Connexion Forward Link Waveform Design

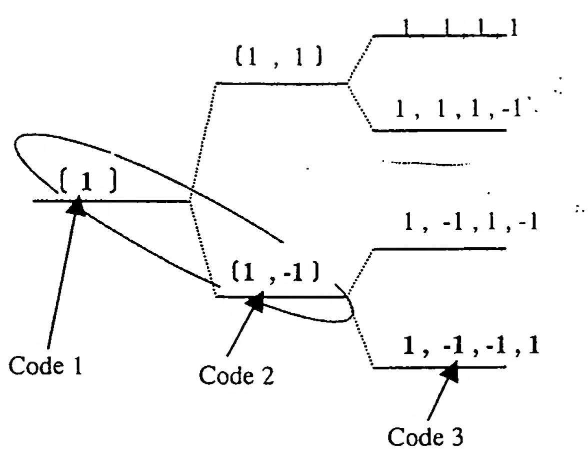

Figure 4. Example of the Generation of a Tree of Variable Length, Orthogonal Spreading Codes

PN sequence spreading is used in addition to the proposed spectral spreading design, insuring full transponder channel spreading, giving all user receive modems on a particular transponder to operate with some amount of VLO coding gain.

PN sequence spreading would be used for the highest data rate channel to spread the bandwidth to fill the channel.

The effect of the assignment of orthogonal coding (with its associated spreading factor) is to reduce the data rate in order to sustain some margin from the BER degradation area of operation. CBB's design keeps away from the situation of reduced throughput due to high PER by the use of forward error correction coding with a sharp BER versus Eb/No response.

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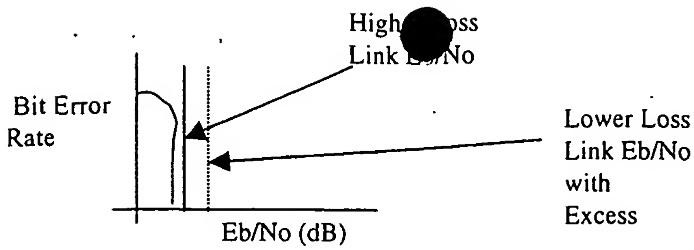

Figure 5. Bit Error Rate versus Eb/No Condition for the Situation in Figure 1

On the satellite communication link, the advantage of the proposed concept would be for the geostationary satellite delay pipe would be able to support more packets for the lower data rate link, improving the packet throughput for the lower data rate link (Figure 5). For the current condition, all user receive modems would get the same packet throughput rate. In conclusion, by speeding up data transmission to the areas with the ability to support those higher data rate links, then the slowest data rate link can also achieve increase in packet throughput due to the extra time slots afforded to it.

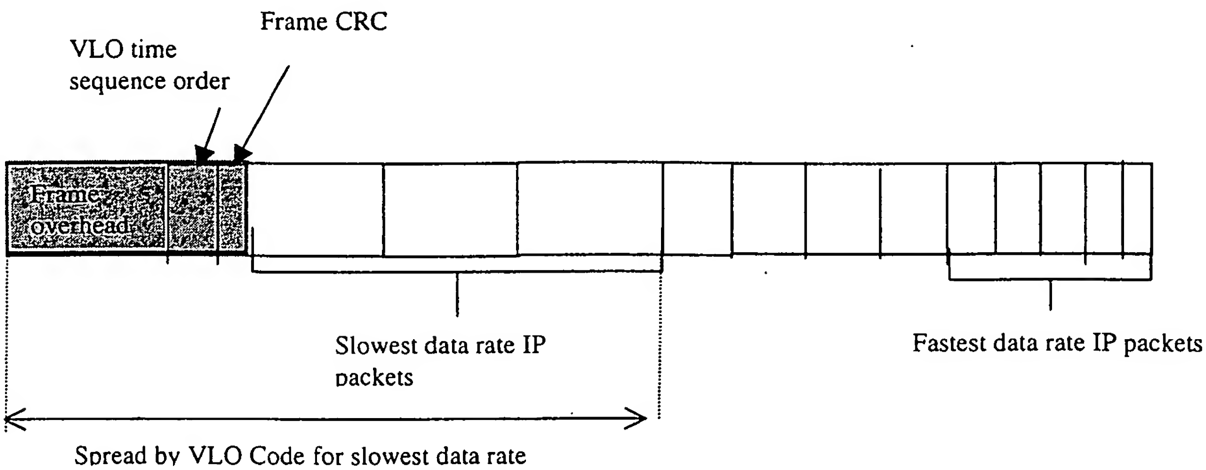

Figure 6. Forward Link Modulation with Variable Data Rate IP Packets. Fixed IP packet length assumed.

For the link layer, there is no modification of ViaSat's link layer design for Connexion.ViaSat concatenates a set of variable length IP packets into a frame. Variable packet length in this case is also influenced by user receive modem data rate.

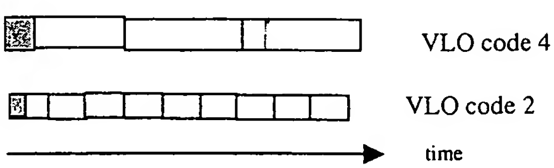

Figure 7. A Set of Link Layer Frames Sent Concurrently through Satellite on Forward Link Distinguished by VLO Code

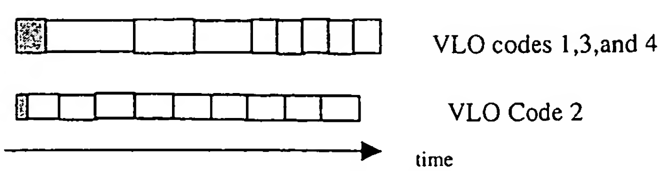

Figure 8. Concurrent Frames with a Variable Data Rate Frame

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Variable length orthogonal coding (VLO) allows multiple frames to be transmitted concurrently as illustrated in Figures 7 and 8. Orthogonal spreading allows the concurrent transmission with no interference and full user data seperation at the receiver.

For the cases of Figures 7 and 8, each of N concurrent frames would share the RF transmit power of the satellite transponder. This power sharing directly impacts a frame's Eb/No, and must be considered when determining the data rate(s) transmitted within a frame.

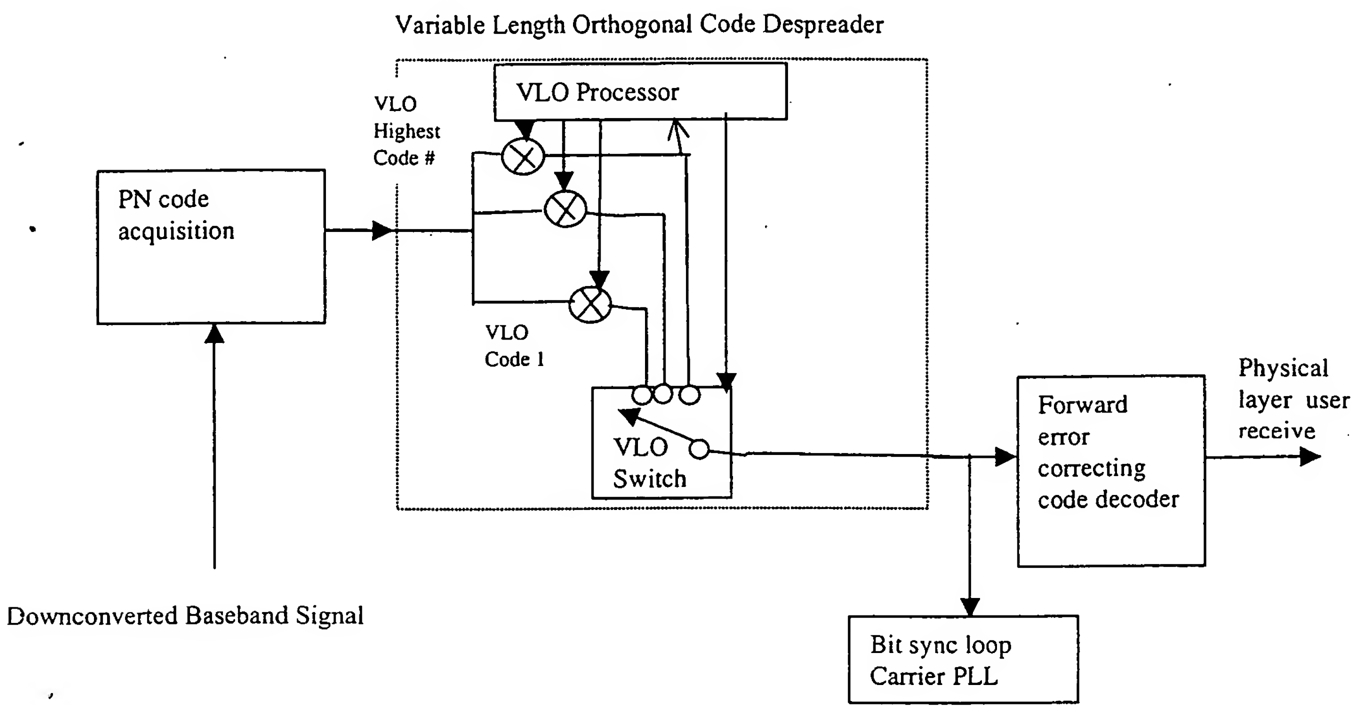

Figure 9. Forward link demodulator design

The VLO processor uses the VLO sequence order to send properly timed switching commands to the VLO switch. The PN code acquisition could be performed by a coherent data-directed phase lock loop. The code acquisition function and VLO spreading function together form a matched filter, matched to the symbol's spreading waveform.

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The demodulator in Figure 9 would read and use the time sequence of VLO packets(overhead in the frame described in Figure 6). In the example of Figure 6, there would be the following VLO time sequence ordering: (3,4,4). The frame overhead would be set at the lowest data rate as would the frame CRC, which includes the VLO overhead in its error detection responsibilities.The ordering of packets is set so that the lower data rate demodulators can switch off after demodulating their packets to avoid incurring high error rates from attempting to demodulate the faster data rate packets.

The faster data rate demodulator could accurately demodulate the lower data rate packets by appropriately setting the VLO despreading filter. The faster data rate channel could discard undesired packet just as easily by achieving bit sync for the lower data rate packets and switching in the FEC decoder when the faster IP packets occur in the link layer frame.

Other Related Efforts
In a related patent disclosure entitiled "Forward Satellite Links using Multiple Simultaneous Data Rates" by Mike de la Chappelle and Dave Parkman, the inventors describe choices for forward data rates with each data rate on a separate transponder. The method proposed in this disclosure delivers different forward data rates over the same satellite transponder. Also, the proposed method can cover a wide dynamic range in user receive modem link margins, for example, 5 Mbps to 16 Kbps would cover a 24 dB link margin differential across the coverage region of the satellite beam in 3 dB increments.

Another approach would be to vary the gain packet by packet through the transponder and leave the transponder in an fixed gain mode. Transient distortions as a consequence of the change in transponder amplification process would effect adjacent packets. Use of this approach on a satellite communication channel is not favored. The preferred mode to operate a satellite transponder is near its saturation point of amplification using constant amplitude modulation techniques, such as the offset QPSK (OQPSK) modulation used for Connexion.

The use of burst modems for cable ISPs achieves similar results to those proposed in this patent disclosure. The burst data rates are achieved by using different levels of bandwidth efficiency in the modulation, for example, 64 QAM(6 bits/Hz) bursting to 256 QAM (8 bits/Hz). The increase in data rate from 64 QAM to 256 QAM is 33%. The proposed method achieves data rate transmission changes in increments of 100%.

Additional Areas to Apply this Patent
Other uses include use for cable ISPs instead of burst modems for the source to user link and for wireless LAN architectures to provide the right amount of RF to various users in case there is tight demand for RF power and frequency in a implementation configuration. The resource assignment method claimed in this patent disclosure could also be applied to GSM 3G, and to other satellite broadcast/multicast systems.

Summary
The proposed method for this invention allows users in similar link margin regions to operate simultaneously with Eb/No values that yield sufficiently low bit error rate and, as a result, low Internet protocol packet error ratio/improved IP throughput. The physical layer data rate is adapted to maintain sufficient positive link margin.

The method proposed in this patent disclosure allows flexibility in bandwidth/data rate assignment to multiple users on a single receiver modem or to multiple receiver modems; it allows a mixture of real time and IP data services to be delivered simultaneously; and it allows different quality of service to be delivered simultaneously to multiple users on a single receiver modem or to multiple receiver modems.

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